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Ingestion rates of *Artemia* nauplii for different larval stages of *Macrobrachium rosenbergii*

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Abstract

The functional response between ingestion rate and food concentration was determined for each larval stage of *Macrobrachium rosenbergii*. *Artemia franciscana* nauplii were supplied at 2, 4, 6, 8, 10 and 12 per milliliter. The nauplii were counted by sight using a Pasteur pipette and transferred to Petri dishes containing 40 ml of brackish water (12‰) lying on the top of black plastic. One larva at each stage was individually placed into each Petri dish containing different food density. After 24 h, each larva was removed from the Petri dish and the leftover nauplii were counted. The amount consumed was determined by the difference between the initial and final number of nauplii. Ingestion rate (I) increased as food density (P) increased and was defined by the model $I=I_m(1-e^{-kP})$. The results suggest four levels of ingestion during larval development. The first level includes stages II, III and IV, with average maximum consumption of about 40 nauplii/day; the second level includes stages V and VI, with consumption of approximately 55 nauplii/day; the third level includes stages VII and VIII, with consumption of 80–100 nauplii/day. The fourth level includes stages IX, X and XI, in which the high values for maximum ingestion (I_m) exceed the load capacity of the medium. The low values for constant k (that may correspond to the adaptability of the food to prey characteristics, such as, size, mobility, etc.) obtained for stages IX, X and XI indicated that *Artemia* is not an adequate prey and there is necessity of a supplementary diet. The best relationship between predator and prey seemed to occur during stage IV. Results obtained in the present work may subsidize future researches and serve as a guideline for practical considerations of feeding rates.
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1. Introduction

Diet is a fundamental aspect in larval culture of decapod crustaceans (Jones et al., 1997; Correia et al., 2000; Valenti and Daniels, 2000). In general, species cultivated for commercial purposes are small and have a small buccal opening and little vitellinic reserve. Therefore, exogenous food is needed 1 or 2 days after hatching. In addition, while several developmental stages occur, morphology, behavior and nutritional needs change (Loya-Javellana, 1989; Sorgellos and Léger, 1992; Jones et al., 1997; Lavens et al., 2000). Generally, live food supplies all the necessary nutrients for development and can contribute with exogenous digestive enzymes that aid in digestion (Kurmaly et al., 1990; Jones et al., 1993; Kamarudin et al., 1994).

Studies on the ingestion rate of live food have been conducted with several larvae of shrimps and prawns, such as: *Penaeus marginatus* (Gopalakrishnan, 1976); *Penaeus indicus* (Emmerson, 1980, 1984); *Pandalus borealis* (Wienberg, 1982); *Penaeus kerathurus* (Yúfera et al., 1984); *Palaemonetes varians* (Yúfera and Rodriguez, 1985a); *Palaemon serratus* (Reeve, 1969; Yúfera and Rodriguez, 1985b, 1987); *Metapenaeus ensis* (Chu and Shing, 1986); *Lysmata wurdemanni* (Zhang et al., 1998). However, research conducted up to this date is insufficient to establish a feeding schedule for species of economical importance.

The food for culture of *Macrobrachium rosenbergii* larvae consists basically of newly hatched *Artemia* nauplii (Lavens et al., 2000) supplemented with inert food (Valenti and Daniels, 2000). Feed consumption by larvae is dependent upon numerous factors related to culture conditions specific for site, and scientific knowledge is not enough to base an adequate feeding schedule. Hatcheries, in general, either maintain a constant *Artemia* supply (about 5 nauplii/ml/day) or increase the density over culture period (Aquacop, 1983; Daniels et al., 1992; Valenti et al., 1998). Although these common practices yield positive results, larval ingestion rates may vary, thus presenting peaks and lows of ingestion at certain stages. Consequently, overfeeding of nauplii in some phases of culture may occur, generating waste and elevating the concentration of toxic nitrogen compounds. On the other hand, the larvae may be underfed during some phases, thus resulting in reduced growth rate and cannibalism.

Recently (2001), there has been a shortage of *Artemia* cysts and prices have increased greatly. Therefore, any management that improves feeding efficiency of *Macrobrachium* larvae is important in reducing feed costs. Supplying the optimal amount of *Artemia* nauplii during each developmental stage contributes to not only reduction in production costs, but also a minimization of problems related to water quality in larviculture. Therefore, more efficient utilization of *Artemia* could significantly maximize productivity and profitability.

The goal of this study was to investigate daily consumption of *Artemia* nauplii by *M. rosenbergii* larvae, relative to density of nauplii, during their ontogenetic development. The resulting knowledge may subsidize the development of improved feeding schedules that should allow for more efficient utilization of *Artemia* in the postlarval production of *M. rosenbergii*.

2. Material and methods

This work was conducted at the Crustacean Biology Laboratory, Aquaculture Center, UNESP (Jaboticabal, SP, Brazil), in a controlled temperature room. The larvae were

obtained from four ovigerous *M. rosenbergii* females obtained from the broodstock at Crustacean Sector, CAUNESP. Larviculture was carried out to supply larvae at different developmental stages needed to conduct the trials. Newly hatched larvae were stocked into a closed recirculating system consisting of a 120-l conical bottom, cylindrical tank equipped with a heater. Density was about 90/l and water salinity was kept at 12‰. The principal water quality variables were monitored and kept within the range recommended by Valenti et al. (1998) and Correia et al. (2000). Temperature, ammonia and nitrite were measured daily and pH, salinity and dissolved oxygen, weekly. Larvae health (eye surface, hepatopancreas, necrosis and/or missing appendages and general pigmentation) was checked according to Aquacop (1983) just before collecting for each trial. The larvae were fed exclusively newly hatched *Artemia* nauplii, supplied ad libitum (more than 12 nauplii/ml) twice a day.

For each developmental stage (II to XI), six densities of *Artemia* nauplii were tested: 2, 4, 6, 8, 10 and 12 per milliliter. The experimental design was completely randomized with 6 treatments and 15 replications. The tests were not carried out with larvae in the first developmental stage because these larvae do not feed even when food is available (Mooler, 1978; Barros and Valenti, 1997). The different larval stages were identified according to Uno and Kwon (1969).

Newly hatched *Artemia franciscana* nauplii (originating from Great Salt Lake, USA) were used to feed larvae in the experiment. Cysts were disinfected by soaking for 30 min in a 2 g/l calcium hypochlorite solution and transferred to a tank filled with 5‰ salinity water for incubation. After 18 h, nauplii were collected, rinsed with freshwater, counted by sight using a Pasteur pipette and transferred to Petri dishes containing 40 ml of brackish water lying on the top of black plastic. The water used in the trials was previously collected from the larval tank and filtered using 125-μm nylon screen. One larva at each stage was individually placed into each Petri dish containing different food density. After 24 h, each larva was removed from the Petri dish and the leftover nauplii were counted. The amount consumed was determined by the difference between the initial and final number of nauplii. Only intact individuals were considered as still available.

Water temperature in the Petri dishes was monitored at the beginning and at the end of each trial. All other water quality variables were measured in the larviculture tank just before collecting water to fill the Petri dishes. A photoperiod of 12-h light/12-h dark was maintained by four 40-W daylight fluorescent lamps setup just above the Petri dishes. The angle of lighting was 90°. In addition, indirect sunlight was provided during the day by means of windows along side.

Average number of nauplii consumed daily by the larvae in each stage was calculated. To determine variation in consumption among all six treatments, daily average values obtained for ingestion were compared by one-way ANOVA (F-test) followed by Tukey pairwise comparison when significant differences were found. Differences were considered to be significant when $P<0.05$.

The mathematical model that describes daily consumption of *Artemia* by the larvae as a function of nauplii density was analyzed. The ingestion curve was adjusted for each larval stage and was described by the following equation:

$$I = I_{\mathrm{m}}(1 - \mathrm{e}^{-kP})$$

where I=ingestion rate (nauplii/larvae/day); I_m=maximum ingestion rate (nauplii/larvae/day); k=constant; P=prey density (nauplii/ml).

3. Results

Average water temperature in the storage tank was 30.0 °C and in the Petri dishes 28.2 °C. Other mean values for the measured water quality variables were assumed to be the same for both tank and Petri dishes. Average salinity was 12.9‰, pH 7.9, ammonia and nitrite ranged from 0 to 0.1 mg/l, and light intensity was about 200 lx. The level of dissolved oxygen of the water was close to saturation value. Survival in the storage tank at the end of experiment was about 50% and larvae presented good health during all culture.

The lowest average ingestion rate was 9.3 nauplii/larvae/day, for larval stage XI, larvae at a density of 2 nauplii/ml; the highest average ingestion rate was 82.2 nauplii/larvae/day, obtained for stage X, at a density of 10 nauplii/ml (Table 1). Individual ingestion ranged from 0 nauplii/larvae/day, observed for stage VI, at a density of 2 nauplii/ml, to 184 nauplii/larvae/day, at a density of 12 nauplii/ml for stage XI. Wide variation in nauplii consumption by larvae in the same stage was observed, independent of food density. Coefficients of variation were calculated to be between 28% and 85%, but generally lower than 50%.

The pattern of ingestion was similar for densities of 2, 4 and 6 nauplii/ml. In general, ingestion rate increased up to stages VII–VIII and decreased in the final stages (IX–XI) (Table 1). For larvae provided with densities of 8 nauplii/ml, the reduction in ingestion was only observed from stage X onward (Table 1). At a density of 10/ml, the rate of ingestion increased significantly from stage II to X, reaching 82 nauplii/larvae/day; at stage XI, ingestion decreased to 47 nauplii/larvae/day. At 12 nauplii/ml, average rates of ingestion varied widely between consecutive stages up to VII. However, nauplii ingestion increased until a relatively stable plateau at about 70 nauplii/larvae/day was reached from stage VIII onward (Table 1).

Table 1
Average daily ingestion rate (mean±S.E.) by *M. rosenbergii* larvae for each *Artemia* nauplii density and zoeal stage

Larval stage	Nauplii density (number/ml)					
	2	4	6	8	10	12
II	15.7±1.5 a	21.9±2.0 ab	29.7±2.2 abc	43.7±4.6 c	32.2±2.8 bc	41.7±5.9 c
III	12.7±1.4 a	28.9±2.9 b	27.7±4.0 ab	34.2±4.7 b	41.4±4.2 b	34.5±4.6 b
IV	14.5±2.6 a	32.9±5.3 a	34.7±5.9 a	37.3±7.1 a	38.9±7.2 a	30.2±6.4 a
V	20.9±3.3 a	45.8±8.5 ab	47.5±5.3 b	51.8±6.3 b	46.9±4.8 b	60.5±6.6 b
VI	18.3±2.8 a	19.9±3.0 ab	39.3±5.4 bc	40.1±7.2 c	48.1±4.7 c	43.3±4.4 c
VII	28.2±5.5 a	41.7±7.0 a	45.9±4.9 ab	55.0±7.7 abc	69.0±7.5 bc	80.1±6.7 c
VIII	22.9±3.0 a	37.7±4.9 ab	45.8±4.7 abc	48.6±5.8 bc	65.1±6.7 c	65.6±8.4 c
IX	13.6±1.8 a	28.9±5.4 ab	36.0±4.8 ab	53.6±5.4 bc	73.0±6.7 c	72.9±9.9 c
X	11.3±1.8 a	23.1±4.3 a	29.8±6.5 a	28.3±3.6 a	82.2±8.2 b	70.2±6.9 b
XI	9.3±1.1 a	20.1±3.1 b	24.9±4.2 b	35.0±4.3 bc	47.4±7.6 cd	77.1±12.3 d

Means with different letters in a row are significantly different at $P<0.05$.

Table 2
Values of maximum ingestion rate (I_m) and constant k calculated using the regression equation, as well as coefficient of determination (r^2) for each stage of *M. rosenbergii* larvae

Stage	I_m	k	r^2
II	44.5	0.200	0.80
III	40.1	0.243	0.86
IV	36.9	0.383	0.77
V	57.1	0.299	0.85
VI	53.5	0.175	0.80
VII	99.4	0.119	0.93
VIII	77.1	0.156	0.95
IX	369.8	0.019	0.96
X	601,036.9	0.997×10^{-5}	0.83
XI	176,631.2	0.300×10^{-4}	0.91

Rates of ingestion of *Artemia* nauplii by *M. rosenbergii* larvae generally differed among food concentration. This difference was significant for all larval stages, with the exception of stage IV. Significant differences were observed for average ingestion values between the highest and the lowest food concentration, but generally, densities between 4 and 8 nauplii/ml yielded similar consumption rates by larvae for each stage (Table 1).

For larvae in stages II–VIII, the regression equation used to describe the mathematical model of daily ingestion rate for *M. rosenbergii* larvae represented quite well the data on nauplii consumption obtained during this phase of development. This model suggests a saturation value of ingestion that would not be exceeded when nauplii concentration increased.

Table 2 shows the values for maximum ingestion rate (I_m), constant k and coefficient of determination (r^2), obtained from the regression equation. The results suggest four levels of ingestion during larval development. The first level includes stages II, III and IV, with average maximum consumption of about 40 nauplii/day; the second level includes stages V and VI, with consumption of approximately 55 nauplii/day; the third level includes stages

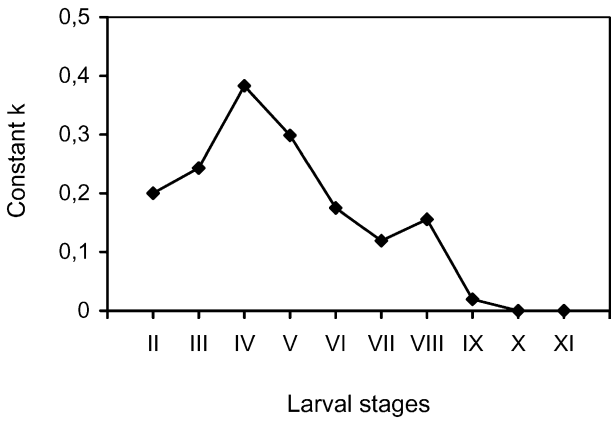

Fig. 1. Specific rate constant k plotted against larval development stages.

VII and VIII, with consumption of 80–100 nauplii/day. The fourth level includes stages IX, X and XI, but estimated values obtained from the adjusted equation exceed the load capacity of the medium.

The values obtained for constant k were plotted versus the different stages of larval development (Fig. 1). This value increases from stages II to IV, and decreases to almost zero during the final stages of development (IX–XI).

4. Discussion

The large variation in the ingestion rates by larvae in the same developmental stage observed in our study of *M. rosenbergii* seems to be a common phenomenon in several species of crustaceans (Anger and Dietrich, 1984). This variation may result from different stages of the molt cycle of the prawn or specific differences in the capacity of the larvae to perceive prey. Studies about daily feeding rate for some Crustacea species, such as *Menippe mercenaria* (Mootz and Epifanio, 1974), *Hyas araneus* (Anger and Dietrich, 1984; Anger et al., 1989; Anger, 1990), *Carcinus maenas* (Dawirs and Dietrich, 1986) and *Ranina ranina* (Minagawa and Murano, 1993a), showed that ingestion rate changes during molting cycle. In some species, ingestion is higher during postmolt (Anger, 1990), while for other species, peak ingestion occurs during intermolt or premolt (Minagawa and Murano, 1993a). In our study, phases of the molting cycle were not determined, but all phases may have been represented through the 15 replicates. Thus, the collected data represent daily average consumption by larvae in each stage.

In general, decapod larvae do not specifically orientate towards a food resource. Rather, they depend on chance encounter to capture food (Mooler, 1978; Meyers and Hagood, 1984; Stickney and Perkins, 1981; Kurmaly et al., 1989, 1990). However, Barros and Valenti (1997) observed individual changes in senses acuity while studying the feeding behavior of *M. rosenbergii* larvae. These authors observed that only a small fraction of individuals detected and pursued *Artemia* nauplii as well as food particles in motion. Thus, this small fraction of individuals composing a population would be more efficient in obtaining available resources, and probably, ingest more. Such differential ability would result in higher variability in ingestion among individuals at the same developmental stage.

The stabilization or decline in daily ingestion rate during the last larval stages of crustaceans, fed food of uniform size, can result from a stabilization of nutritional needs of the animals or loss in capture efficiency due to necessity of larger prey (Valiela, 1984; Yúfera and Rodriguez, 1985b). The first hypothesis did not seem applicable to *M. rosenbergii*, because ingestion increased during the final development stages as nauplii concentration increased (Table 1). Analysis of ingestion rates for each larval stage relative to nauplii density indicated that, for II to VIII stages, ingestion increased with food availability to a maximum value (I_m). This observation suggested that a saturation point from which nauplii concentration did not seem to affect ingestion significantly existed. Although the proposed regression equation fitted the data obtained for stages IX, X and XI, the saturation point falls far from the studied concentration intervals. The saturation point for these stages could be determined more precisely in new studies using higher nauplii densities. Therefore, the relationship can be described by a linear model, indicating that the

larvae can consume even more if nauplii concentration increases. This fact suggests the need of more food to fulfill the energy demand of *M. rosenbergii* during the last three larval stages. Supplemental feeds other than *Artemia*, as commonly used in commercial hatcheries, may be essential in this phase. Higher energy demand to fulfill metabolic costs and/or growth, as well as preparation of the organism for metamorphosis during the last larval stages of *M. mercenaria* (Mootz and Epifanio, 1974), *Rhithropanopeus harrisii* (Levine and Sulkin, 1979), *P. kerathurus* (Yúfera et al., 1984), *P. indicus* (Emmerson, 1980, 1984) and *Penaeus monodon* (Kurmaly et al., 1989) has been demonstrated.

On the other hand, for stages IX, X and XI, consumption is significantly superior in high nauplii density (10 and 12 nauplii/ml). Possibly, as the larvae grow, the relationship between prey size and predator size results in capture of nauplii being more difficult. Therefore at low densities, ingestion rate may be even lower for larvae in final development stages, because higher nauplii density is needed to make capture possible. Observations of larvae feeding behavior have shown that from stage VIII onward, larvae do not grab nauplii with their appendices, but they create a current of water towards their mouth in order to ingest the food (Barros, 1996). Such a pattern demands high nauplii concentration to attain satisfactory ingestion by the larvae. Ingestion reduction by the predator, when prey number is reduced, might be a strategy to maximize energy. When food concentration is very low, the energy consumed as part of the feeding process can be higher than the energy supplied by the ingested food itself.

Holling (1959) named the relationship between ingestion rate and food concentration functional response. According to this author, three basic types exist. In type I, ingestion increases linearly with increasing number of preys until it reaches a satiation point. In type II, ingestion rate increases with increasing food density until it stabilizes at a maximum value, thus resulting in an asymptote. The third type displays a sigmoid response, with a lower and upper limit, beyond which ingestion rates decrease. The ingestion rates of *M. rosenbergii* larvae from stages II to VIII, with respect to concentration of live food, probably follow the type II model. Similar functional response was observed for other decapods, such as *H. araneus* (Anger and Nair, 1979), *P. indicus* (Emmerson, 1980), *P. kerathurus* (Yúfera et al., 1984), *P. serratus* (Yúfera and Rodriguez, 1985a), *P. varians* (Yúfera and Rodriguez, 1985b), *M. ensis* (Chu and Shing, 1986), *P. monodon* (Loya-Javellana, 1989) and *R. ranina* (Minagawa and Murano, 1993b). In the last larval stages (IX–XI), the regression equation gives very high maximum ingestion rates. In these stages, the functional response is type I, when the food consists of *Artemia* nauplii at the densities studied.

The mathematical model proposed in this work fitted the data and described *M. rosenbergii* functional response adequately up to stage VIII. The proposed equation permits determination of maximum ingestion rate (I_m) and constant k, relative to each developmental phase. Maximum ingestion rate values obtained from the equation represent the maximum average value consumed by the larvae when food density is not limiting. The average ingestion values observed (Table 1) were generally lower than I_m (Table 2). Thus, nauplii density is a limiting factor for ingestion. Possibly, when nauplii concentration is lower than the optimum value, the larvae ingest less *Artemia* than it needs.

Aquacop (1983) suggests supplying 5 nauplii/larvae/day for *M. rosenbergii* from the second day of culture and increasing 5 nauplii/larvae every 1 or 2 days. Thus, more than 40

nauplii/larvae/day would be supplied only from the 12th day on, when the larvae have attained stages V and VI. A comparison between I_m values obtained in the present work with the values reported by Aquacop (1983) indicate that in the initial stages, the amounts were underestimated by the latter, because values close to 40 nauplii/larvae/day are needed from stage II onward. Between stages V and VI, 55 nauplii/larvae/day would be necessary, which is lower than the value reported by Daniels et al. (1992). These authors suggest a daily ingestion rate of 100 nauplii/larvae/day from the 15th day onward. In the final stages (between the 13th and 30th day), Aquacop (1983) suggests values of about 45 nauplii/larvae/day, which is much lower than the results obtained in the present work (more than 75 nauplii/larvae/day). This debit energetic may be provided by supplementary diet, recommended by these authors from the 12th day onward, and normally used by commercial hatcheries. Supplemental feed formulations and feeding guidelines including live and inert feed are presented by Aquacop (1983), Daniels et al. (1992) and Valenti et al. (1998).

The constant k measures the curvature of the regression line (Knight, 1968), that is, the change in the ingestion rate (I) with respect to prey density (P) (Valiela, 1984). If we consider that this constant represents the rate at which maximum ingestion is reached, this value would also correspond to the adaptability of the food to prey characteristics, such as, size, mobility, etc. Therefore, higher k values imply more appropriate food for the predator, because even at low densities, adequate ingestion would occur. The constant k determined in our study might represent an adjustment of *Artemia* nauplii with respect to *M. rosenbergii* larvae in each developmental stage. The newly hatched nauplii used had the same origin and, therefore, size, mobility and nutritional value were constant during the larval cycle. Values of k increased up to stage IV and then decreased gradually to almost zero in stages IX, X and XI (Fig. 1). The best relationship between predator and prey occurs for larvae in stage IV, when these larvae ingest more nauplii at low densities than larvae in final developmental stages (Table 1). This conclusion is strengthened by the fact that this was the only stage in which no significant differences were observed in nauplii consumption among tested densities. At this stage, mouth and pereiopods are more developed relative to earlier stages, which increases the capture efficiency of the larvae. Barros and Valenti (1997) observed that stages II and III of *M. rosenbergii* larvae ingest only the abdomen of the nauplii; complete ingestion occurs only from stage IV onward. The capacity of the larvae to capture prey increases in the following stages corresponds to the development of buccal apparatus and locomotion appendices. However, the suitability of nauplii as food seems to diminish, probably due to small size compared to the larvae. In stage IV, nauplii size corresponds to approximately 20% of the average total length of larvae (2.5 mm according to Uno and Kwon, 1969). This relationship decreases to about 8–6% in stages IX to XI, when the larvae reach an average length between 6 and 7.7 mm, respectively. Larvae in the final developmental stages (IX, X and XI) are restricted in their ability to capture this prey. Therefore, *Artemia* nauplii should be replaced by larger preys in this phase.

Prey size and density are not independent variables when ingestion rate is determined (Valiela, 1984). Sick and Beaty (1974) investigated consumption of *Artemia* nauplii by different sizes by *M. rosenbergii* larvae in stage XI. They observed higher ingestion rates when the size of the nauplii supplied corresponded to about 19% of larvae's average length. Alam et al. (1995) observed that consumption of *Moina micrura* by *M. rosenbergii* in stage VI increased when the relationship between the size of prey and predator was approx-

imately 18%. These data suggest that the most favorable relationship of prey size to *M. rosenbergii* length is approximately 0.2. This indicates that in larviculture, the ideal size of live food to be supplied is approximately 20% of larvae length. Yúfera et al. (1984) observed that consumption of the rotifer *Brachionus plicatilis* by larvae of *P. kerathurus* diminished during development. These authors concluded that rotifers are not adequate food type from mysis II onward, due to their reduced size.

According to Holling (1959), functional response accounts for two very important parameters for predator consumption, among others, when prey size does not vary. These are capture or attack rate and handling time. As the larvae develop, attack rate tends to increase and handling time decreases, thus resulting in an increase in ingestion rate. Barros and Valenti (1997) observed that for stages II and III of *M. rosenbergii* larvae, capture and ingestion time of *Artemia* nauplii was approximately 10 min. For stage IV, this time was reduced to about 3.5 min. Thereafter, the time decreased gradually, reaching about 1 s for stages IX–XI. Although stages IX–XI larvae have more developed appendices and buccal apparatus, capture of small prey and particles available in low concentrations is difficult. As mentioned previously, larvae in these stages create a flow of nauplii towards the mouth, similar to filtering animals, instead of capturing one nauplius at once. Therefore, at higher concentrations, ingestion should be higher. In fact, increasing food concentration lead to higher ingestion rates (Table 1), thereby reinforcing the hypothesis that *Artemia* nauplii is not an effective food source for ingestion by *M. rosenbergii* larvae during the three last developmental stages. This information is important for culture and might be the basis for the low productivity displayed in larviculture using only *Artemia* as food.

To establish an adequate feeding schedule for *M. rosenbergii* larviculture, the minimum concentration of *Artemia* necessary to maximize capture efficiency and daily amount of nauplii ingested by the larvae needs to be considered. These two factors vary with the larval stage and are the basis for the suitable nauplii supply for larviculture. Considering the current great cost of *Artemia* cysts, a multistage culture should be performed to improve larvae capture efficiency and more effectively use the live feed. Larvae would be stocked at very high densities for the first 10 days, and then, concentration would be decreased in the next two or three phases.

It should be noted that the results obtained from Petri dishes might not be the same as in larviculture tanks, which are larger and different in shape. In addition, larvae behavior may be affected by competition with other larvae and feeding strategies. Therefore, mass rearing culture should be tested. According to Daniels et al. (1992), to insure efficient use of *Artemia* in mass culture systems, larvae should be monitored daily to evaluate fullness of gut as an indication of adequate consumption and health, as well as monitoring *Artemia* remaining after larval guts are full. Results obtained in the present work may subsidize future researches and serve as a guideline for practical considerations of feeding rates.

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